

REPLACEMENT SHEET

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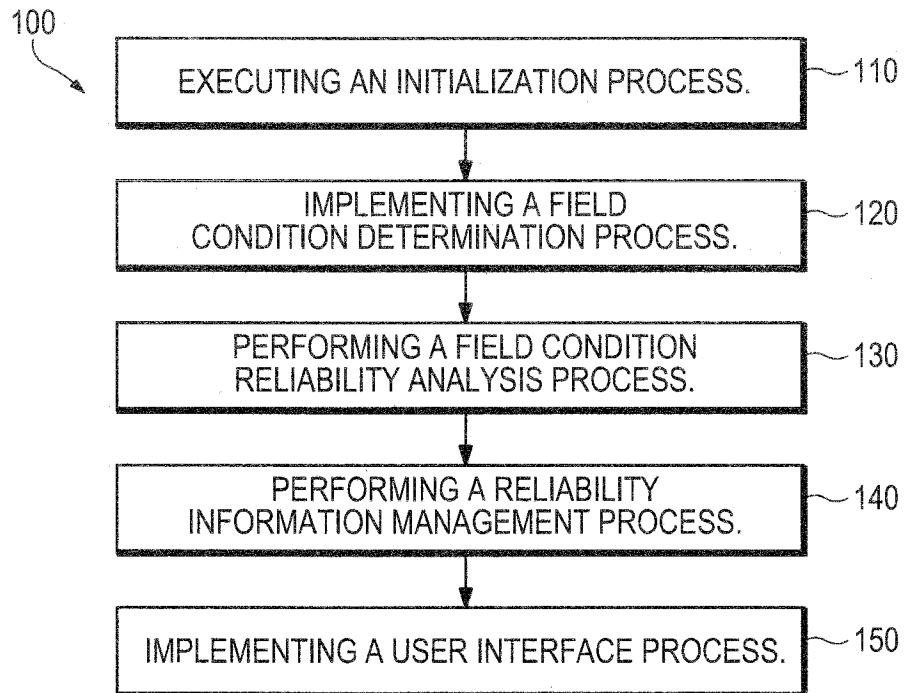


FIG.1

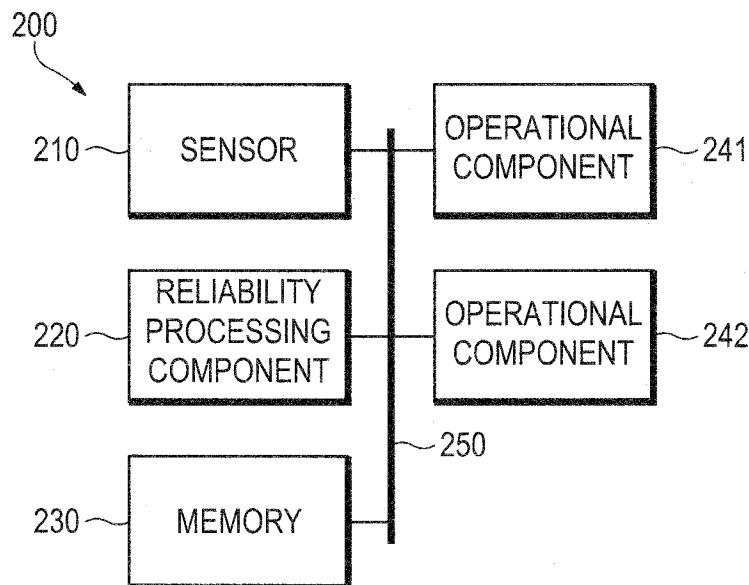
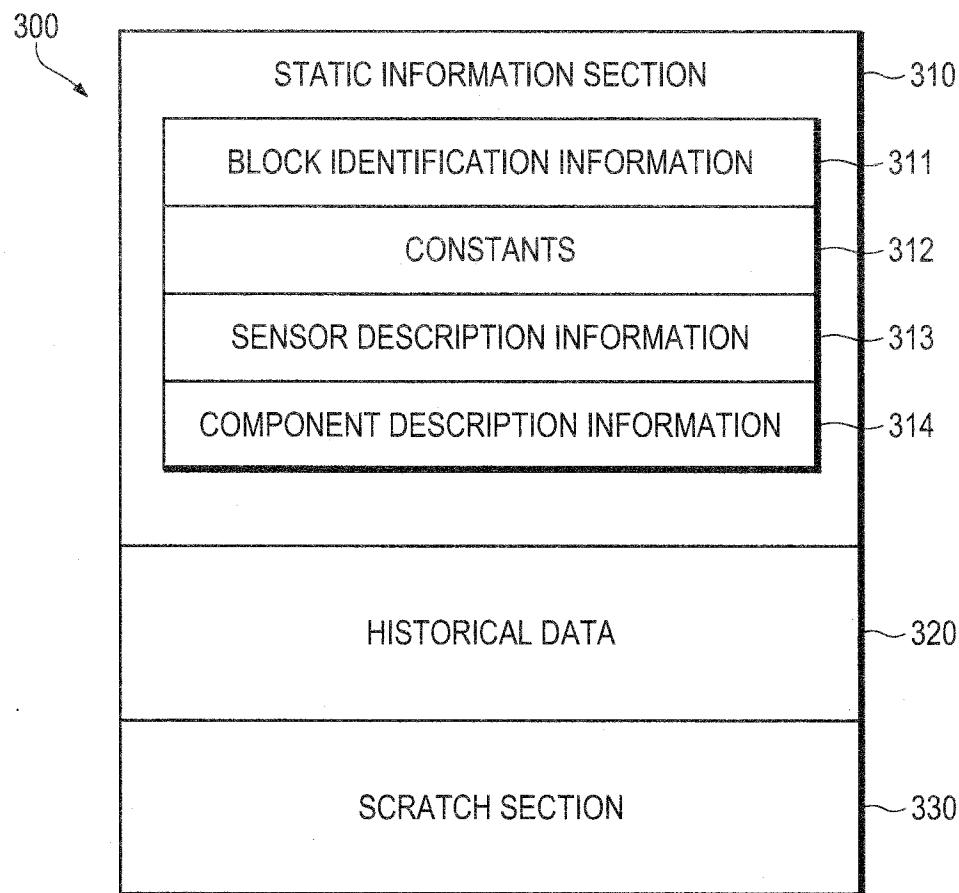


FIG.2

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**FIG.3**

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Historical temperature data - Flash structure  
 Block 0 - Static data

**Block identification**

This is the signature to validate the block 0 data. Checking this format FW will know data are present. The version number is necessary for every future variation of the structure. The base address is : 1FC0 0000 + 2Mbytes = 1FE0 0000

string_id	24	\$\$** _xRELIABILITY_ **\$\$
version	1	Structure version number - 1
format_time	4	Time of Format - minutes since 1/1/70 00:00:00
blk_chksm	2	Block checksum
reserved	33	Reserved for future use

**Time constants**

These are the constant values for sampling and saving data. If the save time is greater than 1 what is saved is the average temperature read in the interval. The offset of this block is fixed at 64 bytes from the base address of the flash block.

blk_id	2	=0x4254 "BT"
blk_chksm	2	Block checksum
bkg_t	1	Time for sampling background task - $\delta$ - in minutes
averagesample_t	1	Max time for temperature sample - $\Delta t_{maxav}$ - multiples of $\delta$
flashsave_t	1	Max time to save data to Flash - $\Delta t_{maxf}$ - multiples of $\delta$
flashclearsave_t	2	Max number of consecutive compress. rec. - $\Delta n_{maxcl}$
reserved	55	Reserved for future use

**Sensors description**

The sensors are listed based on the position on the list. Each one has an ID number, the 2wire channel and the 2wire address to univocally identify it. The sensor ID this parameter is the same reported in the TEMP component for the board. Every sensor will be numbered from 1 to N based on component's structure. Because we have different type of sensor it is possible that the read temperature is adjusted. For example reading the temperature for a sensor inside an ASIC gives the junction temperature so it is adjusted to get the case temperature.

$$\begin{aligned} \text{if } sadjt_j == 0 & \quad T_{eff} = T_{read} + sadv_j \\ \text{if } sadjt_j == 1 & \quad T_{eff} = T_{read} * (1 + sadv_j / 100) \end{aligned}$$

The offset of this block is fixed at 128 bytes from the base address of the flash block.

blk_id	2	=0x4253 "BS"
blk_chksm	2	Block checksum
sensor_num	1	Number of sensors for the board - s
sensor_j	4	Sensor ID - sd <sub>j</sub>
sensor_2w_chn	1	Sensor 2wire channel
sensor_2w_addr	1	Sensor 2wire address

**FIG.4A**

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400 (CONTINUED)

sensor_adjust_type	1	Sensor reading adjustment type - sadjt <sub>j</sub> - 0 = absolute - 1 = percent
sensor_adjust	1 *s	Sensor reading adjustment value - sadj <sub>j</sub>
sensor_DT_average	1	Delta Temp to be considered average $\Delta T_{avth}$
sensor_DT_max	1	Max Delta Temp to be recorded with comp. $\Delta T_{maxth}$

**Component descriptor**

One component is an HW module that can be correlated to a reliability function. Usually components are ASICs having an internal temperature sensor, but it is not limited to that. For this reason the form used to calculate the local temperature for the component is assumed of the form:

$$T_c = C + \sum_s c_{ws} T_s$$

Where  $T_s$  is the temperature sampled in the generic sensor. The constant C and the weights  $c_{ws}$  can be determined by pre-FCS measurements and multivariate analysis. The acceleration factor is then:

$$A_c(T) = \exp((1/k) \sum_{nf} Eaf(1/(273 + T_{ref}) - 1/(273 + T_c)))$$

component_num	1	Number of the tracked components - c
comp_id	4	Component ID (32bit integer)
comp_type	1	Comp Type: PortAsic, Bridge, Fabric, ...
comp_inst	1	Comp sequential number
fr_ref	8	Reference failure rate $\Lambda_c$ (1/hr, double)
spec_comp numb	1	Number of this specific component
comp_archit	1	Component architecture csa 0 = serial 1 = redundant
actv_en_num	1	*c Number of activation energy - nf
actv_en	8* nf	Electronic failure activation energy - Eaf(c,f) - eV (double)
temp_accel_ref	1	Reference temperature for accel. Factors $T_{ref}$ (°C)
temp_w_const_coeff	8	Constant term for temperature definition C (double)
temp_w_exp_coeff	s*8	Weight for expansion temperature determination $c_{ws}$ (double)

Block 1-30 - Historical data

This part contains historical temperature data. For the format please see par. 4.

Block 31 - Scratch sector

This sector is used as scratch during erase/write of a complete data sector

**FIG.4B**

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RAM Memory			
bit-sz	Symbol	Mem-sz	Description
16	$\delta$	1	Reading interval in minutes (15 min)
16	tsave	1	Saving values to NV time (tsave * $\delta$ )
32	t1	1	Limit time for infant mortality ( $t1 * \delta$ )
32	t2	1	Limit time for wear out ( $t2 * \delta$ )
64	ba	1	Min value for $\beta$ (at t=0)
64	bb	1	Max value for $\beta$ (reached at $t=2 * t2$ )
8	nf	1	Number of possible electronic failures
64	Eaff[ ]	nf	Activation energy per failure / $8.63 \cdot 10^{-5}$ (eV/k)
8	Nj	1	Component number
32	ComplDj	Nj	Identifier
64	$\Lambda j$		Reference failure rate
64	Trefj		Reference temperature ( $^{\circ}\text{K}$ )
8	Cnumj		Number of this specific components
8	Ttype		Temperature measurement (CaseT, indirect)
8	Carch		Architecture (serial, redundant)
64	mj		% of traffic factor
8	Prefj		% of traffic reference factor (50)
64	PosFct		Position factor
64	$\Lambda s$	1	System failure rate
32	t	1	Total ticks
64	B	1	Value for instantaneous $\beta$ $B=1$ $If (t < t1) B=ba+((1-ba)/t1) * t$ $If (t > t2) B=1+((bb-1)/t2) * (t-t2)$
64	Rrefj[ ]	Nj	Reference reliability index per component $Rrefj[j]=\exp[-(\Lambda j[j] * \delta * t) B]$
64	Rrefs	1	System reference reliability index $Rrefs=\exp[-(\Lambda s * \delta * t) B]$
64	FRrefj[ ]	Nj	Failure rate index per component $FRrefj[j]=(\Lambda j[j]) B * B * (\delta * t) B - 1$
64	FRrefs	1	System failure rate index $FRrefs=(\Lambda s) B * B * (\delta * t) B - 1$
64	Ajft[ ]	Nj * nf	Accelerator factor per component per failure $Ajft[j,f]=\exp[Eaff[f] * ((1/Trefj[j]) - (1/(Tj[j]+273)))]$
64	Ajt[ ]	Nj	Accelerator factor per component $Ajt[j]=\sum_f (Ajft[j,f])$

FIG.5A

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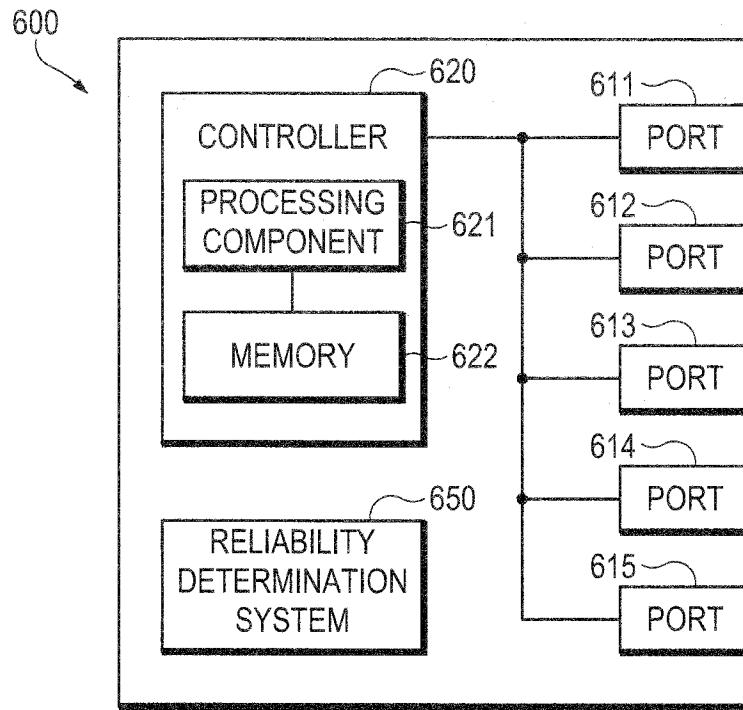
500 (CONTINUED)

bit-sz	Symbol	Mem-sz	Description
64	Ljt[ ]	Nj	Instantaneous failure rate per component $Ljt[j]=Ajt[j] * \Lambda j[j]$
64	SRjt[ ]	Nj	Instantaneous contribution to the reliability index $SRjt[j]=(Ljt[j])^B * B * (\delta * t)^{B-1}$ $SRjt[j]=SRjt[j] * \exp[-(Ljt[j]) * \delta * t]^B$
64	Rjt[ ]	Nj	Reliability index per component $Rjt[j]=Rjt[j]-SRjt[j]$
64	Lst	1	System instantaneous failure rate $Lst=\sum_j (Ljt[j])$
64	SRst	1	System inst. contribution to the reliability index $SRst=(Lst)^B * B * (\delta * t)^{B-1}$ $SRst=SRst * \exp[-(Lst * \delta * t)^B]$
64	Rst	1	System reliability index $Rst=Rst-SRst$
16	BFsz	1	Ring buffer size
16	BFidx	1	Next avail. Row in ring buffer
32	tofT	BFsz	Reading time
8	Tin		Intake Temperature (°C)
8	Tex		Exhaust Temperature (°C)
8	Tj[Nj]		Case Temperature per component (°C)
64	Lj[Nj]		Inst. failure index per component
64	Ls		System Inst. failure index
64	Rj[Nj]		Reliability index per component
64	Rs		System reliability index

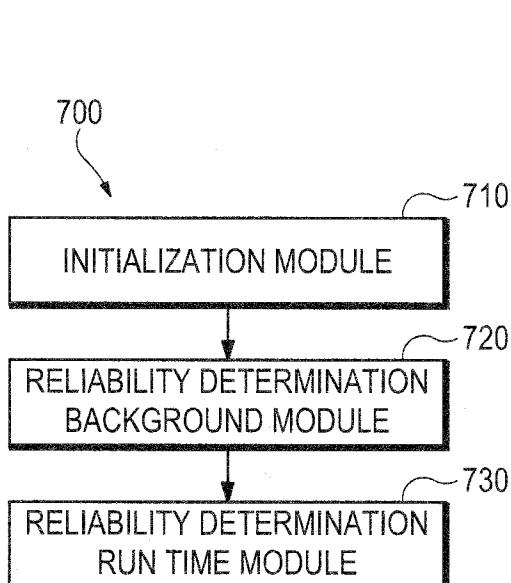
FIG.5B

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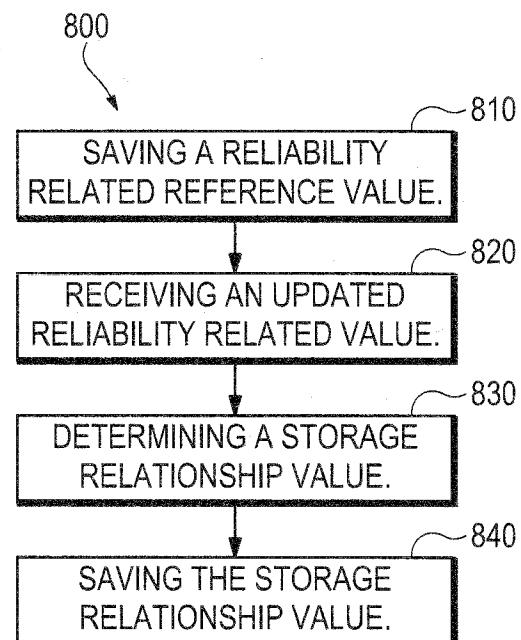
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**FIG.6**



**FIG.7**



**FIG.8**

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SENSOR	SENSOR	SENSOR	TIME INTERVAL
27	50	30	0C98719h
28	52	29	0C9871A3h
35	53	25	0C9871B2h

**FIG.9A**

SENSOR	SENSOR	SENSOR	TIME INTERVAL
27	50	30	0C987194h
+1	+2	-1	1
+7	+1	-4	1

**FIG.9B**

SENSOR	SENSOR	SENSOR	TIME INTERVAL
00011011b	00110010b	00011110b	0C87194h
0001b	0010b	1001b	01h
0111b	0001b	1100b	01h

**FIG.9C**